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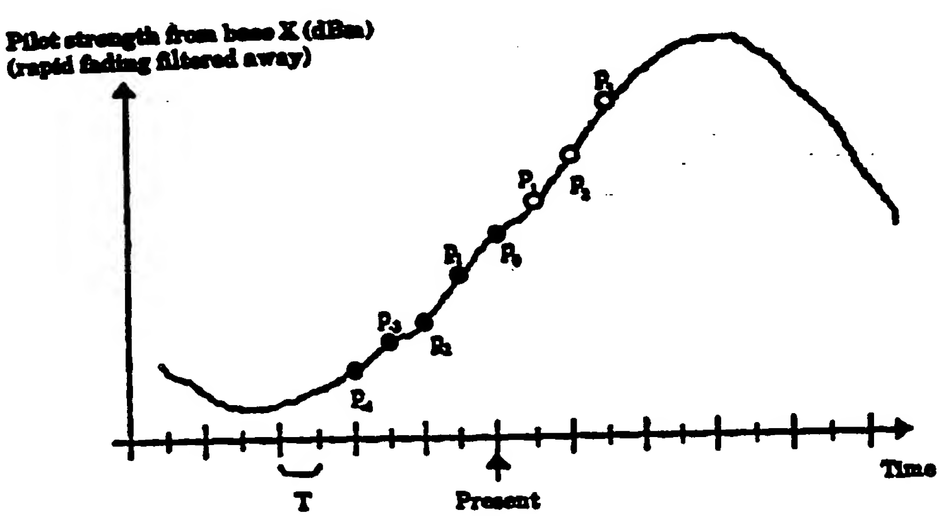

(57) Abstract

In a cellular telecommunication system one and the same mobile unit can be connected to two or more base stations, which implies that the system operates with macro diversity. Respective concerned mobile unit operates with an active set-function or a connection pattern which indicates and estimates the mobile unit's connection situation in relation to concerned base stations, and decides about changes in the connection situation. In the system the mentioned active set is predicted adaptively by means of previously obtained data or parameters. By the invention are achieved improved system functions at which can be mentioned safe handover-function, better transmission quality in the border areas of the cells, etc.

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TITLE OF THE INVENTION

Method and device at cellular telecommunication system.

TECHNICAL FIELD

The present invention relates to a method at cellular telecommunication system where respective concerned mobile unit at the same time can be connected to two or more base stations, i.e. the system operates with macro diversity. Further, respective concerned mobile unit shall operate with an active set or connection pattern which indicates and estimates the connection situation of the mobile unit in each moment in relation to the base stations concerned, and decides about changes in the mentioned connection situation. The invention also relates to a device at cellular telecommunication system of the by way of introduction mentioned kind.

STATE OF THE TECHNOLOGY

By the PCT-application WO 91/17608 is described a method to predict future measurement values for handoff-decisions. Accordning to the application, measurements are performed of for instance the signal strenght on a transmission. To make possible to make handoff-decisions at an early stage, a prediction of the signal strength is performed at a later point of time. At this an adaptive filter is used. Accordning to the application the mobile can perform measurements on surrounding base stations or vice versa.

By the American patent 4 556 760 can in a cellular mobile telephone system a handoff- filter be used. The

patent describes a filter function which is usable for evaluating for instance amplitude variations at a mobile unit which is moving in the neighbourhood of a cell border.

The filter function offers both long and short averaging of received signal. These averages can be used together with the latest measured value to predict future values.

The American patent 5 267 261 describes a mobile assisted "soft" handoff in a cellular communication system using CDMA. The described method, which is also called base station diversity, implies that communication between mobiles can be made over a number of base stations at the same time. Maintaining of active setting is included in the method. Nothing, however, is mentioned about prediction.

By the PCT-application WO 92/12602 is indicated how handover at mobile radio system is to be performed. The mobile unit measures the strength of signals from surrounding base stations, and bases the handover decision on the basis of increase or decrease of the mentioned signal strengths.

The European patent application 462 952 describes adjustment of output in a digital mobile telephone system. The invention is intended to keep the transmitted power on optimal level, i.e low enough not to disturb, but high enough to be possible to be received at the receiver. The adjustment decision is based on predicted future signal strenght values which in their turn are calculated on previously measured values, for instance signal strength, signal quality, which are averaged.

By the American patent 5 203 010 is shown a cellular radio telephone system. In this the base station measures the signal strenght of the signal from the mobile unit and calculates a future value which it then communicate to surrounding base stations.

DESCRIPTION OF THE INVENTION

TECHNICAL PROBLEM

In CDMA-systems it is comparatively easy to implement macro diversity. Therefore this exists as a natural part in Qualcoms CDMA-system and in the CODIT-project´s (RACE II) system concept and test system. By macro diversity is in this connection meant that a mobile can be connected to more than one base at the same time to keep up a connection. In order to use as much as possible of total received payload signal (from different base stations in the downlink, in the uplink a number of base stations receive the same signal) are then different combination methods used both on mobile- and network side. Normally, if macro diversity is used, a mobile in the border area of a cell is always connected to more than one base. In this way is, among other things, a more secure handover obtained, so called soft handovers, higher quality of transmission in border areas and generally more secure connections in border areas.

A central concept in the connection is "the mobile station active set". The mobile´s active set defines which base stations the mobile at present are connected to. The function "the active set update function" evaluates continuously the mobile´s active set and decides about connections and disconnections, if any, i.e. all changes of the mobile´s active set. The

decisions are based on pilot measurements (each base station has a unique pilot channel with known, often constant and equal output). Which algorithm that is used for deciding about changes of the mobile´s active set is unimportant in the connection, as long as the evalutation is based on the pilot measurements.

In principle one is aiming at keeping the strongest base stations in the mobile´s active set. Strongest implies in this connection those bases which experience the smallest attenuation (the sum of the distance attenuation and the slow fading, rapid fading is filtered away). In this way power is saved and by that capacity. Consequently optimally a mobile in macro diversity only uses the links which at present have the smallest propagation losses (the rapid fading disregarded).

To achieve the above, the mobile detects and measures continuously the strongest pilots. The rapid fading is filtered away, in CODIT median filters are used for this, the values are after that collected to a measurement report. Measurement reports are sent at a certain pace to system management, where the mobile´s active set is evaluated (thus the report goes to the active set update function). In CODIT a second filtering is made before the measurement values are used, but how the filtering is managed is unimportant for the invention. The problem is that measurement values which are used for the evaluaton of the mobile´s active set are "old", the total time between measurement point of time and point of time for a resulting change of the mobile´s active set can be 1-2 seconds or more. This is due to delays in the measurement process itself, in the filtering, in the reporting and in delays at signalling

and transmission of data, and in the connection of a new base (synchronization).

The delay brings about increased interference level, bigger variation of received signal/noise relation (i.e lower quality) and increased power consumption. Generally can be said that a CDMA-system with macro diversity (and power adjustment in up- and downlink) is comparatively sensible to delays of this kind. Optimally would be to know the pilot strengths in the future, during the time that an active set shall be valid. This is also in principle what the invention is aiming at. Even if the description here is based on a CDMA-system with macro diversity based on pilot strenght measurements, the formulation of the problem is more general. The problem exists in all mobile systems with macro diversity (according to the definition which has been made here), where the macro diversity is controlled by means of measurements which are correlated with the sum of the distance attenuation and the long fading between base and mobile. (These two quantities are in the general case much correlated in up- and downlink). It is assumed that it is not possible to design a system without delays.

THE SOLUTION

What can in the main be regarded as significant for the new method and device will be apparent from the following patent claims.

DESCRIPTION OF FIGURES

The invention will be described in the following while at the same time references are made to enclosed drawings where:

Figure 1 in curve form shows pilot strenght after filtering away of rapid fading, at which measurement values and future measurement values are indicated on the curve, and T represents a measurement reporting period.

Figure 2 in the form of block diagram shows an adaptive active connection prediction where the memory processing is not shown but central processing of the measurement values are assumed, at which the system is digital/discrete and is shifted at the same pace as the measurement values arrive, and measured pilot strength is the value after filtering away of rapid fading.

DETAILED DESCRIPTION

The invention is based on the fact that the slow fading is predictable, at least during the time intervals, i.e. one or a few seconds, which is of interest here. The same also applies in principle to the distance attenuation during the mentioned time interval. This because the pattern of movement of a vehicle does not change instantaneously, a car does not turn 180° at 70 km/hour. A walking user, on the other hand, is not possible to predict, but in this case the distance attenuation is neither considerably changed during studied time interval. Thus, instead of basing the evalutation of the mobile´s active set on the latest batch of received measurement values (after filtering), i.e. only on the information in the latest received measurement report, previously received reports are also used to estimate the situation in an immediate future (i.e. one or a few seconds later). Two fundamental strategies are suggested, see Figure 1, for the strongest pilots:

A. Predict the pilot strength one or more periods of time (i.e. measurement reporting periods, in the interval 0,25 - 2,0 seconds) ahead in time. Base the evaluation on these predicted values. Thus make use of available measurement values p_0 up to and including p_{-k}, k>0, for predicting p_l, l=1,2. Use a one step- or multistep predictor. At multistep prediction either a true multistep predictor can be realised, or a one step predictor which is iterated can be used. More about predictors follows.

B. Predict the time average of the pilot strength a number of time periods ahead in the time. Base the evaluation on these predicted values. Two variants are possible, to predict separate pilot strength values and calculate the time average, or to predict the time average directly. Accordingly use available measurement values p_0 up to and including p_{-k}, k>0, for predicting for instance $p_1/2+p_2+p_3/2)/T$, where T is the reporting period which is known.

Both methods thus require one (the case in strategy A and possible in strategy B) or more predictors (can be the case in strategy B) per pilot which is detected in the mobile. This calls for memory capacity and calculating capacity. This should not cause any problems in the future generations of mobile systems. Possible predictors follow. Furtermore are needed functions to secure the stability, which will also be touched upon. Finally are needed functions for automatic connection and disconnection of the predictors, which will also be discussed. The lattar are needed because it is probably pointless (with the time interval and the measurement

reporting periods which are discussed here) to predict in indoor environment.

Three possible embodiments of predictors are suggested:

1. If one restrict oneself to linear predictors, an RLS-predictor (Recursive Least Squares) is the best choice. RLS-predictors are possible to analyse (will however take some time in the general case) and are comparatively easy to implement. We skip the mathemathical description here and establish that there exist robust methods with reasonable calculation - and memory consumption. By using an RLS-algorithm one can obtain BLUE (Best Linear Unbiased Estimation). Consequently it is not possible to construct a better linear average true predictor with lower fault variance (the fault is the difference between predicted and real value). There may however be (there are in most cases) predictors which are not linear or not average true with lower variance on the fault.

2. A more sophisticated method is to use a neural network as predictor. Neural predictors are considerably more difficult to analyse (a complete analysis on a larger predictor can be an impossibility, which can be proved). In any case good results can be obtained even if the preparations are considerably more extensive. It is in most cases possible to get compact and robust, not necessarily linear or average true, predictors by using neural networks. The field is a science in itself.

3. A third method which is neither quite uncomplicated, is to use an ML-predictor (Maximum

Likelihood). The method is based on that the measurement values comes from distributions which are at least partly known, which definitely is the case here. The slow fading is approximatively lognormal, the measurement faults are possible to estimate and the distance attenuation is dependent on the movement pattern of the mobile. As the movement pattern is possible to analyze, an approximative distribution can be obtained. It can be shown that ML-predictors which are linear (which is not a demand) can reach BLUE.

There is always a small risk that a predictor becomes instable during one or a few samples. Different predictors are more or less robust, often depending on how it is implemented even if the same mathematical algorithm is used. Beside building in stabilisation criteria in the predictor itself, which requires comparatively much additional work, there are always parameters which control the inertia in the adaption process. A correct balance often gives a very stable solution. A completing method, to secure the stability, which is suggested here is to use the knowledge about the measurement signal:

- Measure continuously the difference between two consecutive measurement values, Δ_m, with a gliding window. Decide Δ_t, so that $P(|\Delta_m|<\Delta_t)=95\%$ (for instance) within the interval, i.e the probability that $|\Delta_m|$ is below Δ_t is 95% within the interval. A more simple variant is of course to use a fixed Δ_t, the value of which is decided by previous measurements and considering the measurement report period.

- Measure continuously the difference between two consecutive predicted values, Δ_p, If $|\Delta_p|$ exceeds Δ_t,

then restrict the output value, i.e. the predicted value, from the predictor so this is not the case any longer.

The method has for almost obvious reasons a very stabilizing effect, especially at multistep prediction where one iterates up a one step predictor. If the threshold value is not set too low, the goodness of the predictor will not be influenced of any note. This method can be used at initial simulations.

When predictors are used it is always possible to check the goodness in previous predictions. This by comparing previous predicted values with measurement values. This gives an opportunity to disconnect the predictor if the prediction faults become too large. In certain surroundings it can be difficult to predict future values, in these cases it is better to disconnect the predictor and use the measurement values directly.

A simple method is to continously compare with the fault in an imagined predictor which uses the latest measurement value as a predicted value (in other words no prediction at all). If the prediction faults at a mobile thus are too large, according to the above, during a certain time period, the predictors will be coupled by, and and the meaurements values will be used directly.

When the fault rate decreases, the predicted values will be used again. The analogy with selection diversity is not altogether misleading. This method is not used at initial simulations.

The foundation stones of the invention are the predictor, the stability control and the efficiency

control, schematically connected in Figure 2. Before this there is the measurement process itself and the filtering for elimination of rapid fading. After there is the evaluation routine which decides if, and in that case how, the mobile´s active set shall be changed. A known evaluation routine which is produced within CODIT exists. A similar routine is used in Qualcom´s system.

The invention can be used in mobile CDMA-system with macro diversity with the meaning which is indicated here. The invention can be directly realised in the CODIT system. More generally the product can be used in the mobile systems of the third generation, if the macro diversity is implemented and suitable measurement channel is available (shall be correlated to the slow fading on up- and downlink and of course the distance attenuation). Demands are also made on the measurement intensity, calculation- and memory capacity. There is, however, no demand that the measurements shall be performed at the mobile even if this will simplify the use. The invention is possible to implement by means of measurements on the network side instead. The invention is usable in systems where an increased importance is attached to, by means of measurements and measurement value processing, increase the capacity and the transmission quality.

The different parts individually, possibly with exception of the efficiency control, are built on in itself known technology. The total system and the field of use is however new. Known alternative methods (CODIT and Qualcom) are low pass filtering of the measurement values. The interference level can be lowered in both up- and downlink, and the quality of up- respective downlink can be increased. The gains are expected to be higher after a more exakt design, trimming and analysis.

The invention is used foremost in mobile CDMA radio systems och might also be used in modern TDMA-system, for instance of the type DECT. The invention can also be used for the mobile radio systems of the third generation, compare UMTS/FPLMTS which probably will be CDMA-based. By the invention is achieved higher quality of the radio transmission, higher capacity, a smaller number of base stations, which in its turn leads to cheaper installation, more satisfied users, which in its turn give obvious competition advantages.

PATENT CLAIMS

1. Method at cellular telecommunication system where respective concerned mobile unit at the same time can be connected to two or more base stations, i.e. the system operates with macro diversity, and respective concerned mobile unit operates with an active connection function or active set function which indicates and estimates the connection situation of the mobile unit in relation to concerned base stations and decides about changes in the connection situation, c h a r a c t e r i z e d in that in the system the connection situation/active set is adaptively predicted by means of previously obtained data or parameters with the aim to make improved system functions, for instance more secure hand-over function, better transmission quality in the border areas of the cells etc.

2. Device at cellular telecommunication system where respective concerned mobile units at the same time can be connected to two or more base stations, i.e. the system operates with macro diversity, and respective concerned mobile unit operates with an active connection function/active set function which indicates and estimates the connection situation of the mobile unit in relation to concerned base stations and decides about changes in the connection situation, c h a r a c t e r i z e d in that the system is arranged to, depending on previously received data or parameters, make adaptive prediction of the connection situation/active set with the aim of getting improved system functions, for instance more secure hand-over function, better transmission quality in the border areas of the cells etc.

3. Device according to patent claim 2, c h a r a c t e r i z e d in that the prediction is performed one or a few seconds ahead in the time and is based on data or parameters with comparatively long backward holding from the wiev of point of time.

4. Device according to patent claim 2 or 3, c h a r a c t e r i z e d in that the pilot strength is predicted one or more time periods in an interval between 0,25- 2,0 seconds ahead in the time, and that evaluation will be based on these predicted values, at which available measurements values p_0 up to and including p_{-k}, where k>0, for predicting p_l, where l=1,2.

5. Device according to any of the patent claims 2-4, c h a r a c t e r i z e d in that a one step- or a multistep predictor is included, at which in the case with multistep predictor a true multistep predictor is included, or in the case with a one step predictor this is iterated.

6. Device according to any of the patent claims 2-5, c h a r a c t e r i z e d in that the time average of the pilot strength will be predicted a number of time periods ahead in the time, after which the evaluation is based on these predicted values, at which in a first case separate pilot strength values are predicted and the time average is calculated in dependence of this prediction, or the time average is directly predicted, at which consequently measurement values p_0 up to and including p_{-k} where k>0 can be used, for instance to predict $(p_1/2+p_2+p_3/2)/T$, where T is the known report period.

7. Device according to any of the patent claims 2-6, c h a r a c t e r i z e d in that one or more predictors per pilot is used and that detection is performed in the mobile, at which memory capacity and calculation capacity is included.

8. Device according to any of the patent claims 2-7, c h a r a c t e r i z e d in that functions for securing of the stability are included, and that devices are arranged for automatic connection and disconnection of the predictors.

9. Device according to any of the previous patent claims c h a r a c t e r i z e d in that linear predictors are included, at which respective linear predictor can consist of an RLS-predictor which operates with an RLS-algorithm.

10. Device according to any of the patent claims 2-9, c h a r a c t e r i z e d in that as predictor is used a neural network.

11. Device according to any of the patent claims 2-10, c h a r a c t e r i z e d in that an ML-predictor is used which operates with measurement values which come from or are obtained from distributions which are at least partly known.

12. Device according to any of the patent claims 2-11, c h a r a c t e r i z e d in that the predictor is arranged with stability criteria, or that parameters which control the inertia in the adaption process are included, at which securing of the stability can use the knowledge about the measurement signal, and the difference between two consecutive measurement values is measured continuously with a gliding window, or that the

difference is measured continuously between two consecutive predicted values.

13. Device according to any of the patent claims 2-12, c h a r a c t e r i z e d in that the goodness in the previous predictions are controllable by for instance comparison of previously predicted values with measurement values, which makes possible for instance that the predictor can be disconnected if the prediction faults become too large, or that the fault in an assumed predictor which uses the lates measurement value as a predicted value is continuously compared.

14. Device according to any of the patent claims 2-13, c h a r a c t e r i z e d in that central memory processing is included in connection to predictor, efficiency control and stability control.

Fig 1

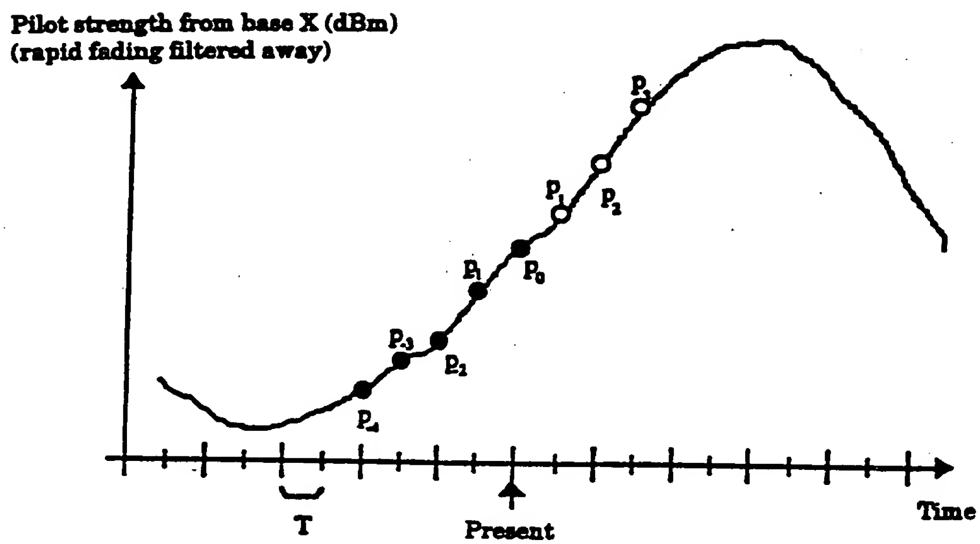
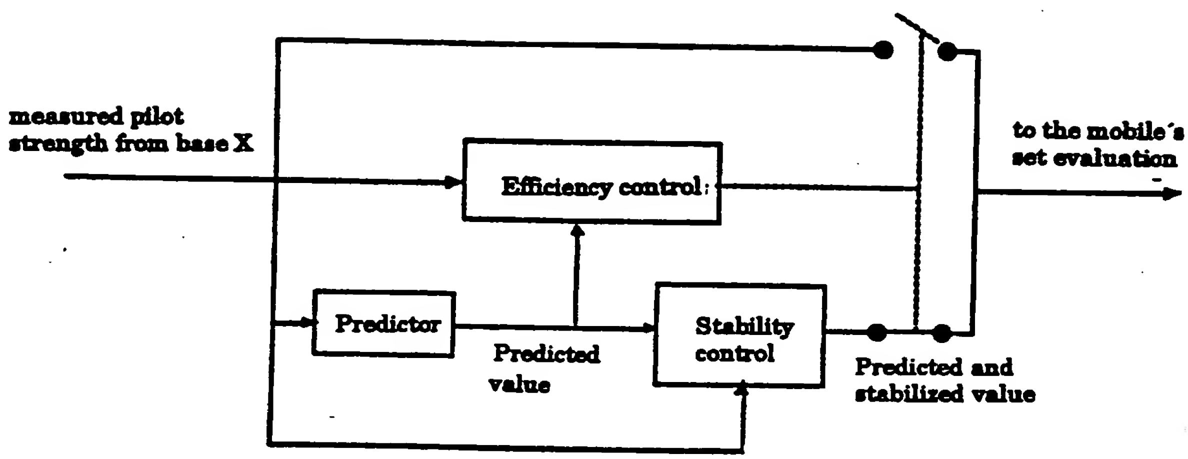

Pilot strength from base X (dBm)
(rapid fading filtered away)
P_{-4}
P_{-3}
P_{-2}
P_{-1}
P_0
P_1
P_2
P_3
T
Present
Time

Fig 2


measured pilot strength from base X
Efficiency control
Predictor
Predicted value
Stability control
Predicted and stabilized value
to the mobile's active set evaluation